APPENDIX J

GEOLOGIC HAZARDS STUDY

North Baja Pipeline, LLC

NORTH BAJA PIPELINE EXPANSION PROJECT

Appendix J
Geologic Hazards Study

Prepared by

Earth Systems Southwest

for

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February 2006

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GEOLOGIC HAZARDS RECONNAISANCE REPORT
NORTH BAJA PIPELINE EXPANSION
& IID LATERAL
LA PAZ COUNTY ARIZONA,
RIVERSIDE AND IMPERIAL
COUNTIES, CALIFORNIA

December 5, 2005

File No.: 08312-03
05-12-718

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December 5, 2005

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Willbros Engineers, Inc.
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Attention: Mr. Carlos Daza

Project: **North Baja Pipeline Expansion & IID Lateral**
La Paz County, Arizona, Riverside and Imperial Counties, California

Subject: GEOLOGIC HAZARDS RECONNAISANCE REPORT

Dear Mr. Daza:

We take pleasure to present this Geologic Hazards Reconnaissance Report prepared for the proposed North Baja Pipeline Expansion project to be constructed from La Paz County, Arizona to Riverside and Imperial Counties, California. This report should stand as a whole, and no part of the report should be excerpted or used to the exclusion of any other part.

This report completes our scope of services in accordance with our agreement, dated August 7, 2001 and amended by Change Order dated October 25, 2005. Other services that may be required are additional services and will be billed according to the Fee Schedule in effect at the time services are provided. Unless requested in writing, the client is responsible to distribute this report to the appropriate governing agency or other members of the design team.

We appreciate the opportunity to provide our professional services. Please contact our office if there are any questions or comments concerning this report or its recommendations.

Respectfully submitted,
EARTH SYSTEMS SOUTHWEST

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Section 1
INTRODUCTION

1.1 Project Description

This Geologic Hazards Reconnaissance Report has been prepared for the proposed North Baja Pipeline Expansion project (NBP) to be constructed from La Paz County, Arizona to Riverside and Imperial Counties, California. The following summary of the projects comes from the Final NOI NOP filed with the California State Lands Commission (CLSC).

North Baja, an indirect wholly owned subsidiary of TransCanada Corporation, has announced its intention to expand its existing natural gas pipeline system in La Paz County, Arizona and Riverside and Imperial Counties, California. The existing North Baja system transports natural gas in a southbound direction. The expansion Project would allow for a northbound flow of gas.

The facilities proposed by North Baja include the following to expand the existing system:

- up to 80 miles of buried 36-inch- or 42-inch-diameter pipeline loop (referred to as the “B-Line”) adjacent to its existing 30-inch- and 36-inch-diameter pipeline (referred to as the “A-Line”) in La Paz, Riverside, and Imperial Counties;
- one metering station at the interconnect with SoCal Gas in Blythe (Blythe Meter Station);
- one pig receiver at the existing Ehrenberg Compressor Station in La Paz County;
- one pig launcher and one pig receiver at the existing Ogilby Meter Station in Imperial County;
- seven mainline valves along the right-of-way; and
- modifications within the Ehrenberg Compressor Station and Ogilby Meter Station to allow for northbound flow.

In association with its proposed expansion, North Baja proposes to construct a 0.5-mile-long, buried 12-inch-diameter pipeline lateral (Blythe Energy Interconnect Lateral) and associated metering and valving from the proposed Blythe Meter Station north to an interconnect with Blythe Energy’s existing supply lateral near Interstate Highway 10 in Riverside County. The lateral would cross privately owned land adjacent to the existing SoCal Gas pipelines and parallel to the D-10-13 Canal and Riviera Drive. North Baja’s preferred alignment would be on the east side of the canal; an alternative alignment on the west side of the canal is also under consideration.

North Baja also proposes to construct a new pipeline lateral and associated facilities in Imperial County from an interconnect near the Ogilby Meter Station to the existing Imperial Irrigation District (IID) El Centro Generating Station. The lateral would deliver up to 100 million cubic feet per day of natural gas to the IID El Centro Generating Station. The IID is considering a future expansion of the station to meet growing power demand.

The IID Lateral facilities proposed by North Baja include:

- approximately 46 miles of buried 16-inch-diameter pipeline lateral (IID Lateral);
- one metering station at the interconnect with the IID El Centro Generating Station (IID El Centro Meter Station);
- one pig launcher at a tap off the A-Line near the Ogilby Meter Station;
- one pig receiver at the IID El Centro Generating Station; and
- up to five block valves along the right-of-way.

North Baja's preferred route of the IID Lateral would cross approximately 30 miles of federal land in Imperial County. The route on federal land deviates from designated utility corridors at one location for about 10 miles, where it would parallel Interstate Highway 8. Most of the IID Lateral would be installed in public road rights-of-way.

Figures of the proposed facilities are provided in Appendix A. Figure 1 depicts a general overview of the major Project facilities. Figure 1 also depicts North Baja's preferred route for the B-Line in the Palo Verde Valley (adjacent to the A-Line along 18th Avenue) and an alternative route under consideration in the Palo Verde Valley along 22nd Avenue. Figure 2 depicts North Baja's preferred route for the IID Lateral and various alternative routes under consideration...

1.2 Purpose and Scope of Study

The purpose for our services was to evaluate potential geologic hazard conditions and to provide professional opinions regarding the geologic constraints for the pipeline project. The scope of work included the following:

- Review of relevant geotechnical and geological literature, including reports and maps from the United States Geological Survey, the California Geological Survey, and other relevant information.
- Limited site reconnaissance of the north half of the pipeline route.
- Engineering analysis and evaluation of the acquired data to identify potential geotechnical or geological constraints that could include: faulting, groundshaking, secondary seismic hazards, landsliding, rock fall hazard, and erosion.
- A summary of our findings and recommendations in this written report.

Earth Systems Southwest previously conducted a quantitative analysis of the soil liquefaction hazard in a separate Liquefaction Hazard Evaluation and Mitigation (LHEM) report.

Screening Investigation Purpose: The purpose of this screening investigation is to evaluate the severity of potential geologic hazards and to screen out areas that have a low potential for geologic hazards. Where this screening investigation demonstrates the absence of geologic hazards along the pipeline route, and if the lead agency technical reviewer concurs with this finding, this screening investigation will satisfy the site-investigation report requirement of CGS Special Publication 117 and no further investigation will be required. Where the findings of this screening investigation indicate the presence of geologic hazards, then a more-comprehensive quantitative evaluation may need to be conducted.

Section 2
METHODS OF INVESTIGATION

2.1 Field Exploration

18th Avenue and Ehrenberg Compressor Site: Earth Systems Southwest conducted geotechnical exploration at the Ehrenberg Compressor Station site and along 18th Avenue. Along the 18th Avenue alignment, four exploratory borings were drilled to a depth of about 51.5 feet on August 9, 2001. At the Ehrenberg Compressor site, six exploratory borings were drilled to depths ranging from 26.5 to 51.5 feet on August 10, 2001.

Ogilby Meter Station: Earth Systems Southwest conducted geotechnical exploration at the Ogilby Meter Station site. One exploratory boring was drilled to a depth of 26.5 feet on September 28, 2001.

Colorado River and All American Canal Crossings: The LawGibb Group under contract to Willbros Engineers, Inc conducted geotechnical exploration for two crossing sites. At the Colorado River Crossing, four exploratory borings were drilled to a depth of about 90 to 91.5 feet on October 9 to 11, 2000. At the All American Canal Crossing, three exploratory borings were drilled to a depth of about 91.5 feet October 16 to 19, 2000.

These boring logs are presented in the Liquefaction Hazard Evaluation and Mitigation and geotechnical reports prepared by Earth Systems Southwest.

2.2 Geologic Studies

Air Photo Review: A set of vertical aerial photographs was reviewed stereoscopically for indications of landsliding or other ground movements at the edge of the Palo Verde Mesa (Milepost 11.6 to 11.8) where the pipeline would traverse up the mesa face.

Site Reconnaissance: Our associate geotechnical engineer/geologist conducted a site reconnaissance of the pipeline route from the Ehrenberg Compressor Station to Ogilby Meter Station site and the IID lateral. The purpose of this limited reconnaissance was to verify site conditions of potentially critical areas of the proposed pipeline route for geologic hazards.

Slope Terrain Analyses: The calculation of slope gradient is an essential part of the evaluation of slope stability. To calculate slope gradient for the terrain within the study area, 7.5- minute quadrangle digital elevation models (DEM) were obtained from the U.S. Geological Survey. These DEMs have a resolution of 30-meters. A slope-gradient map was made from the combined DEMs using the MicroDEM program.

Section 3
DISCUSSION

3.1 Surficial Soil Conditions at Selected Sites

Ehrenberg Compressor Site (Milepost 0): The field exploration indicates that soils consist primarily of an upper surficial layer of silt that is 2 to 8 feet thick, underlain with medium dense to loosely deposited sand and some silty sand.

Colorado River Crossing (Milepost 0 to 0.5): The field exploration indicates that soils consist generally of loose to dense silty sand and sand with some gravel.

18th Avenue Alignment (Milepost 2.4 to 11.6): The field exploration indicates that soils consist generally of an upper layer of cohesive clayey soil underlain by sand to silty sand.

Ogilby Meter Station (Milepost 75.2): The field exploration indicates that soils consist generally of very dense, silty sand.

All American Canal Crossing (Milepost 79.6 to 79.8): The field exploration indicates that soils consist generally of medium dense to dense silty sand.

3.2 Groundwater

Measured Groundwater Levels from Exploration: Free groundwater was encountered in the borings at the following depths at selected sites.

Site	Milepost	Measured Groundwater Depth (feet)
Ehrenberg Compressor	0	17
Colorado River Crossing	0 to 0.5	13 to 23
18th Avenue Alignment	2.4 to 11.6	9 to 16.5
All American Canal Crossing	79.6 to 79.8	29 to 31

However, there is uncertainty in the accuracy of short-term water level measurements. Groundwater levels may fluctuate with irrigation, drainage, regional pumping from wells, and site grading. The groundwater levels detected may not represent an accurate or permanent condition.

Estimated Groundwater Levels in the PaloVerde Valley region: USGS Professional Paper 486-G provides a groundwater contour map of the Palo Verde Valley and region. An excerpt of this map is presented on Figure 9.

Estimated Groundwater Levels in the Imperial Valley region: USGS Professional Paper 486-K provides a groundwater contour map of the Imperial Valley and region. An excerpt of this map is presented on Figure 10.

3.3 Regional Geologic Setting

Ehrenberg Compressor Site, Colorado River Crossing, and 18th Avenue (Milepost 0 to 11.6): These areas lie in the Palo Verde Valley, which consists of approximately 1,000 feet of alluvial and sedimentary gravel, sand, silt, and clay deposits of the Colorado River Flood Plain. The Flood Plain in the Blythe area consists of approximately 100 feet of Younger (Holocene) alluvium consisting of sands, silts, clays, and some gravel. The younger alluvium is directly underlain by approximately 500 feet of older (Pliocene and Pleistocene) alluvium of soils similar to the younger alluvium. These soils are the result of several broad periods of degradation and aggradation by the Colorado River. The alluvial soils in the Blythe area reach to approximately 600 feet where the soil formation changes to a Pliocene age embankment deposit of the Gulf of California known as the Bouse Formation. This formation is composed of tufa and basal limestone overlain by interbedded clay, silt, and sand.

Palo Verde Mesa (Milepost 11.6 to 22.5): The Palo Verde Mesa consists of piedmont on the west side of the Palo Verde Valley that consists of older alluvium with lower terrace deposits at the valley wall. The mesa is dissected with several alluvial washes.

Palo Verde Peak Area (Milepost 22.5 to 36): The NBP route through this area traverses around the base of foothills that comprise the Palo Verde Mountains. The Palo Verde Mountains consist primarily of Tertiary volcanic rocks that form ragged peaks with a topographic high of about 1795 feet above mean sea level. Older alluvium fanglomerate and conglomerate deposits flank the mountains. Some Bouse Formation exposures are found at the base of the mountains. Recent alluvium lies within the floodplain of the Colorado River at the eastern base of the mountains and foothills.

Milpitas Wash to Ogilby (Milepost 36 to 71): The NBP route through this area traverses across the Milpitas Wash, a major alluvial drainage system, piedmont, and alluvial washes in the Arroyo Seco area through the Chocolate Mountains, and piedmont on the southeast side of the Chocolate Mountains. The piedmonts consist of older alluvium that is dissected with numerous alluvial washes.

Ogilby to All American Canal Crossing (Milepost 71 to 79.8): The NBP route through this area straddles the dividing line between the Salton Trough and the Mojave Desert section of the Southern Basin and Range physiographic province. This area lies on the Pilot Knob Mesa near the Algodones sand dunes to the west. The mesa soils consist of older and recent alluvium consisting of fine to coarse-grained sands with gravels, and cobbles.

The Algodones Fault trends northwest to southeast and is inferred to lie nearly parallel with the proposed NBP route from Milepost 75.5 to 79.5. The Algodones Fault is the dividing line between the Salton Trough and Southern Basin and Range.

IID Lateral: The IID lateral traverses across the Salton Trough physiographic province. The Salton Trough is a broad structural depression resulting from large scale regional faulting associated with horizontal slip along the San Andreas Fault System. The San Andreas Fault and inactive Sand Hills Fault bound the trough on the northeast. The San Jacinto Fault Zone bounds the trough on the southwest. The Salton Trough represents the northward extension of the Gulf of California that has experienced continual in-filling with both marine and non-marine sediments since its approximate formation in the Miocene Epoch.

A high level of seismicity from active northwest-trending faults and oceanic-type spreading centers characterizes the Salton Trough. Seismicity in the Salton Trough is concentrated between the offsets of three major transform faults - San Andreas, Imperial, and Cerro Prieto. Geodetic measurement, as well as historic and geomorphic evidence of recent fault movement, indicate a high rate of tectonic activity in the area.

The Imperial Valley is directly underlain by Holocene (0 - 11,000 years before present) Cahuilla Lake beds, which consist of interbedded lenticular and tabular silt, sand, and clay. The Holocene lake deposits are probably less than 100 feet thick. The Pleistocene Brawley Formation underlies the Cahuilla Lake beds. The Brawley Formation consists of at least 2,000 feet of gray clay, sand, and pebbles, which in turn overlie about 6,000 feet of the late Pliocene Borrego Formation. The Borrego Formation consists of lacustrine gray clay and sand. The Borrego Formation overlies an indeterminate thickness of the Pliocene marine Imperial Formation, Alverson Andesite, and Miocene continental sediments of the Split Mountain Formation. Basement rock consisting of Mesozoic granite and probably Paleozoic metamorphic rocks are estimated to exist at depths between 15,000 - 20,000 feet. Thicknesses of the various geologic formations are approximate.

3.4 Geologic Units

The proposed route of the NBP will generally encounter eight mapped geologic units. The mapped units are shown on the Geologic Maps, Figures 3 to 6. For the purposes of screening for geologic hazards, we used published geologic maps at 1:250,000 and 1:125,000 scales, combined with limited field reconnaissance along the proposed route of the pipeline. The following geologic units will be encountered during construction of the pipeline.

Quaternary lake deposits (Ql): The Imperial Valley, where the west section of the IID lateral crosses, is composed of lake deposits of ancient Cahuilla Lake beds that consist of interbedded lenticular and tabular silt, sand, and clay.

Quaternary Alluvium (Qal): Holocene alluvial deposits are mapped across the Palo Verde Valley and numerous washes. The alluvium in the Palo Verde Valley consists of unconsolidated sands, silts, clays, and some gravel. The washes generally consist of unconsolidated sand and gravels with some silts. The mid-section of the IID lateral crosses the East Mesa consisting of Holocene alluvial deposits.

Dune Sand (Qs): Unconsolidated sand and silty sand of both Holocene and Pleistocene origin. Extensive dune sand is mapped to the west of the NBP Milepost 75 to 79.8. The IID lateral crosses the Algodones sand dune field along the All American Canal.

Pleistocene Non-marine Older Alluvium & Fanglomerate (Qc): Dissected flat to gently sloping alluvium is common from Milepost 11.6 to 79.8. These poorly consolidated silts, sands, and gravels typically form desert pavement terraces coated with desert varnish between dry washes. The alluvium is generally locally derived, poorly sorted, angular, and reflects the lithology of the mountainous areas flanking these deposits.

Tertiary Volcanic Rock (Tv): Undifferentiated volcanic rock comprises the Palo Verde Mountains and smaller outcrops near the NBP route.

Bouse Formation (Tbs): Interbedded marine to brackish water limestone, siltstone, sandstone, and tufa of Tertiary origin outcrops intermittently along the base of the Palo Verde Mountains.

Non-marine Clastic Volcanic Conglomerate (Tc): Non-marine clastic volcanic conglomerate outcrops along the NBP route at the flank of the Palo Verde Mountains.

Miocene Non-marine Sedimentary Deposits (Mc): Non-marine sedimentary fanglomerate deposits composed of cemented gravel occur in limited outcrops along the NBP route.

3.5 Geologic Hazards

Geologic hazards that may affect the pipeline include seismic hazards (surface fault rupture, ground shaking, soil liquefaction, and other secondary earthquake-related hazards), slope instability, and erosion. A discussion follows on the specific hazards to the project.

3.5.1 Seismic Hazards

Seismic Sources: Several active faults or seismic zones lie within 93 miles (150 kilometers) of the project areas as shown on Tables 1 through 3 and Figure 7 in Appendix A. The primary seismic hazard to the pipeline project is moderate groundshaking from earthquakes along the San Andreas and Imperial Valley Faults. The Maximum Magnitude Earthquake (M_{max}) listed is from published geologic information available for each fault (Cao et al., CGS, 2003). The M_{max} corresponds to the maximum earthquake believed to be tectonically possible.

Surface Fault Rupture: The NBP route does not lie within any currently delineated State of California, *Alquist-Priolo (A-P)* Earthquake Fault Zones (Hart, 1997). Well-delineated fault lines cross through this region as shown on California Geological Survey (CGS) maps (Jennings, 1994). Therefore, active fault rupture is unlikely to occur along the NBP route. While fault rupture would most likely occur along previously established fault traces, future fault rupture could occur at other locations.

However, the IID lateral crosses the Imperial fault. This fault ruptured in both 1940 and 1979. In 1979, about 50 to 70 cm of cumulative right lateral displacement was measured occurring on two splays of the fault line near Interstate 8 where the preferred IID lateral route crosses. An excerpt of the A-P fault map at the Imperial fault is shown on Figure 8. Based on an estimated characteristic return rate of 79 years and 20 mm/yr geologic slip rate, an expected characteristic fault displacement of about 5 feet (1.6 m) may be anticipated for future ruptures, but could be locally greater as occurred in the 1940 event.

Algodones Fault: The inferred trace of the Algodones fault trends nearly parallel with the proposed NBP from Milepost 75.5 to 79.5. The fault appears to be an ancestral continuation to the southeast of the San Andreas transform fault of southeastern California, southwestern Arizona and northern Sonora, Mexico. The Algodones Fault is shown on most geologic and fault maps of the Yuma area but is concealed by young sediments.

Studies by Woodward-McNeill (1974) and Dames and Moore (1985) for the Salt River Dual Use

Nuclear Plant and the Yuma Water Users Hydroelectric Plant project, respectively, have stated that the most recent activity along the Algodones Fault was pre-Holocene (11,000 years before present). An extensive fault investigation was performed to determine, in part, if the Algodones Fault was capable of future rupture or generating a major earthquake. The investigators found that the Algodones Fault is an east dipping normal fault confined to the western margin of the Fortuna Basin in Arizona (Heath, 1992). No evidence was found to indicate the Algodones Fault projected into California. West of Yuma, west dipping normal faults were identified and these most likely represent the eastern edge of the Salton Trough and are probably related to the East Mesa Fault (Heath, 1992).

A pattern of episodic release of stress in moderate to large events at the north end of the Algodones fault is supported by the study of Quaternary tectonics of the Yuma region conducted by Bull (1974) as part of the Woodward-McNeill report. Analysis of the data from trenches across the Algodones Fault in the Yuma region suggests that this portion of the fault has moved within the last 15,000 years (late Pleistocene). Further, paleosols indicated that characteristic movement along the fault has not occurred as continuous creep but consists of intermittent movement of several feet followed by periods of stability. The total late Pleistocene movement was estimated as 50 feet. The last movement, representing a single earthquake, was about 3 to 5 feet (Bull, 1974).

Imperial Fault: The Imperial fault is a right-lateral fault that connects the oceanic-type spreading centers located at the Brawley Seismic Zone and the Cerro Prieto geothermal area. The Imperial Fault is about 60 miles in length. It has produced at least two large historic earthquakes. The largest events were the 7.0M_w on May 18, 1940 and 6.5M_w on October 15, 1979.

The Brawley fault trends to the north from an intersection with the Imperial Fault at a location about four miles northeast of the City of El Centro. This fault has a surface expression approximately 9 miles long. The Imperial and Brawley faults have ruptured synchronously during past earthquakes. The California Geological Survey assigns a geologic slip rate of 20 mm/year, and a characteristic magnitude Mmax of 7.0 with an average 79-year return period (CDMG, 1996).

Historic Seismicity: The Imperial Valley is among the most seismically active regions in the nation. Figure 7 shows the significant earthquakes that have been recorded in the region. Five significant historic seismic events (5.8M or greater) have significantly affected the Imperial Valley in the last 100 years. They are as follows:

- *Imperial Valley Events* - On June 22, 1915 twin magnitude 6.0 and 5.9M_S earthquakes occurred about an hour apart near El Centro resulting in at least six deaths (Ellsworth, 1990).
- *El Centro Event* - On May 19, 1940 a magnitude 7.1M_S (7.0M_W) earthquake ruptured the Imperial Fault with horizontal offsets up to 19 feet and triggered widespread liquefaction as evidenced by sand boils throughout the valley (Sylvester, 1979).
- *Imperial Valley Events* - On October 15, 1979 a magnitude 6.6M_S (6.5M_W) earthquake ruptured the Imperial Fault again with horizontal offsets of about 2 feet and triggered widespread liquefaction as evidenced by sand boils throughout the valley. A magnitude 5.8M_L event occurred as an aftershock along the Brawley Fault on the evening of October 15, 1979 (US Geological Survey, 1982).

- *Westmorland Event* - On April 26, 1981, a magnitude 6.0M_S (5.9M_W) earthquake occurred 4 miles north of Westmorland and triggered widespread liquefaction. Although there was not surface faulting associated with this earthquake, canals and buildings were damaged. Liquefaction also occurred in the Brawley Seismic Zone after M5+ earthquakes in 1930, 1950 and 1957.
- *Superstition Hills Events* - On November 24, 1987, a magnitude 6.6M_S (6.5M_W) earthquake ruptured the Superstition Hills Fault causing over 15 miles of right lateral offset (26 in. maximum) and triggered liquefaction from the Salton Sea to Seeley. A magnitude 6.2M_L (5.9M_W) event occurred as a foreshock along the Elmore Ranch Fault on November 23.

Secondary Seismic Hazards: Secondary seismic hazards related to ground shaking include soil liquefaction, ground deformation, areal subsidence, tsunamis, and seiches. The site is far inland so the hazard from tsunamis is non-existent. At the present time, no water storage reservoirs are located in the immediate vicinity of the site. Therefore, hazards from seiches are considered negligible at this time.

3.5.2 Ground Shaking and Site Acceleration

The potential intensity of ground shaking motion may be estimated from the horizontal peak ground acceleration (PGA), measured in "g" forces. Included in Tables 1 to 3 are deterministic estimates of site acceleration from possible earthquakes at nearby faults at three representative locations along the pipeline route. Ground motions are dependent primarily on the earthquake magnitude and distance to the seismogenic (rupture) zone. Accelerations also are dependent upon attenuation by rock and soil deposits, direction of rupture, and type of fault. For these reasons, ground motions may vary considerably in the same general area. This variability can be expressed statistically by a standard deviation about a mean relationship.

In our evaluation of peak ground acceleration (PGA) we averaged three attenuation relationships: Boore et al. 1997; Sadigh et al, 1997; Abrahamson & Silva, 1997, and Campbell, 2003. Each attenuation relationship has their strengths and limitations. For this reason, the USGS used an equally weighted average of these four in their National Strong Motion Mapping Program.

The following table provides the probabilistic estimate of the PGA, EPA, PGV and Spectral Accelerations taken from the 2002 CGS/USGS seismic hazard maps and interactive seismic deaggregations available at the USGS National Strong Motion Mapping Program website. These values have been adjusted for alluvium soils, Soil Profile Type, S_D.

Estimate of PGA, EPA, PGV, and Spectral Accelerations from 2002 CGS/USGS Probabilistic Seismic Hazard Maps

Ehrenberg Station, Riverside County, California
Modal Magnitude 7.6, Modal Distance 113 km

Risk of Exceedance	Equivalent Return Period (years)	PGA (g)	EPA (g)(2)	PGV (3) (cm/sec)	Spectral Acceleration Sa (0.2 sec.)	Spectral Acceleration Sa (1.0 sec.)
10% in 50 years (DBE)	475	0.12	0.11	33	0.28	0.19
2% in 100 years (MCE)	2475	0.20	0.20	48	0.51	0.31

Ogilby Meter Station, Imperial County, California
Modal Magnitude 6.9, Modal Distance 45 km

Risk of Exceedance	Equivalent Return Period (years)	PGA (g)	EPA (g)(2)	PGV (3) (cm/sec)	Spectral Acceleration Sa (0.2 sec.)	Spectral Acceleration Sa (1.0 sec.)
10% in 50 years (DBE)	475	0.23	0.23	53	0.58	0.34
2% in 100 years (MCE)	2475	0.42	0.42	84	1.02	0.56

IID Lateral at Imperial Fault, Imperial County, California
Modal Magnitude 6.9, Modal Distance 0 km

Risk of Exceedance	Equivalent Return Period (years)	PGA (g)	EPA (g)(2)	PGV (3) (cm/sec)	Spectral Acceleration Sa (0.2 sec.)	Spectral Acceleration Sa (1.0 sec.)
10% in 50 years (DBE)	475	0.87	0.84	204	2.10	0.83
2% in 100 years (MCE)	2475	0.83	0.83	203	2.07	0.87

Notes:

1. Values are adjusted from soft rock site, $S_{B/C.}$ The soil amplification factors to adjust to Soil Profile Type S_D for PGA, Sa (0.2 sec), and Sa (1.0 sec), are as follows:
   Ehrenberg: 1.5, 1.5, 2.0, respectively.
   Ogilby: 1.2, 1.2, 1.8, respectively.
   IID Lateral at Imperial Fault: 1.0, 1.0, 1.5, respectively
2. EPA = Effective Peak Acceleration, derived from Spectral acceleration (S_A) at period of 0.2 seconds divided by scaling factor of 2.5 for 5% damping.
3. PGV = Peak Ground Velocity, derived from Sa (1.0 sec).
4. DBE = Design Basis Earthquake for California (Uniform) Building Code.
5. MCE = Maximum Considered Earthquake for International Building Code (ASCE 7), deterministic limit at Imperial fault
6. For other locations along the pipeline, a first order estimate of ground motion parameters may be obtained by interpolation between the tables.

3.5.3 Liquefaction

Soil liquefaction is a natural phenomenon that occurs when granular soils below the water table are subjected to vibratory motions, such as produced by earthquakes. Vibrations cause an increase of pressure in the water within soil pores, as the soil tends to reduce in volume. When the pore water pressure reaches the vertical effective stress, the soil particles become suspended in water causing a complete loss in soil strength. The liquefied soil behaves as a thick liquid. Liquefaction can cause excessive structural settlement, ground rupture, lateral spreading (movement), or failure of shallow bearing foundations. Liquefaction is typically limited to the upper 50 feet of the subsurface soils.

Four conditions are generally required before liquefaction can occur:

1. The soils must be saturated below a relatively shallow groundwater level.
2. The soils must be loosely deposited (low to medium relative density).
3. The soils must be relatively cohesionless (not clayey). Clean, poorly graded sands are the most susceptible. Silt (fines) content increase the liquefaction resistance in that more cycles of ground motions are required to fully develop pore pressures. If the clay content (finer than 5 micron size) is greater than 20%, the soil is usually considered non-liquefiable, unless it is extremely sensitive.
4. Groundshaking must be of sufficient intensity to act as a trigger mechanism. Two important factors that affect the liquefaction opportunity are duration as indicated by earthquake magnitude (M) and intensity as indicated by peak ground acceleration (PGA).

The liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (more likely to liquefy). In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as defined in CGS Special Publication 117:

- Areas containing soil deposits of late Holocene age (less than 11,000 years, such as river channels and their historic floodplains), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or
- Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or
- Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Based on these criteria and supplemented by the Liquefaction Hazard Evaluation And Mitigation Study conducted along selected areas the following areas have both the opportunity and susceptibility for soil liquefaction to occur.

Area	Milepost	Measured or Estimated Groundwater Depth (feet)	Geologic Unit	Liquefaction Potential
Palo Verde Valley	0 to 11.6	9 to 17	Qal	Moderate to High
Palo Verde Peak	23 to 25.3 25.3 to 27.5 27.5 to 31.9	40 to 20 20 to 40 5 to 20	Qal Qc/Qal Qal	Low to Moderate Very Low to Low Moderate to High
Milpitas Wash	34.9 to 35.7	43 to 57	Qal	Very Low
All American Canal	79.6 to 79.8	29 to 31	Qc/Qal	Very Low
East Mesa	IID Lateral	Generally 20 to 40 Locally <10 at W side	Qal	Low to Moderate Locally High
Imperial Valley	IID Lateral	Generally 5 to 15	Ql	Moderate to High

Quantitative analyses of the soil liquefaction hazard have been conducted from Milepost 0 to 11.6 and at 79.6 to 79.8. The liquefaction potential for Milepost 27.5 to 31.9 is likely to be similar to the Palo Verde Valley area.

Soil liquefaction potential is most acute along the Imperial Valley section of the IID lateral. Historic occurrence of soil liquefaction has been documented along the Alamo River banks from the 1970 Imperial Valley Earthquake (USGS Professional Paper 1254).

Liquefaction Effects: Soil Liquefaction can cause permanent ground displacements (PGD), ground surface disruption (sand boils, fissuring), and lateral spreading or movement on sloping ground or toward canal or river banks. Based on prior quantitative liquefaction analyses conducted by Earth Systems Southwest and our experience in the area, PGD may range from about 0 to 6 inches. However, at canal banks and especially at the Alamo River within the Imperial Valley, the lateral spreading potential may exceed these values.

3.5.4 Slope Stability

Potential geologic hazards related to slope instability include; landslides, debris flows and rock falls. The impact of these hazards to the site is discussed below.

Landslides: No significant landslides were observed during the site reconnaissance, nor are any known to exist along the proposed NBP Route. The terrain along and immediately adjacent to the pipeline route is less than 25% gradient (except at the edge of Palo Verde Mesa as discussed below). Therefore, the potential for landsliding is low to nil (see Figures 11 and 12).

Debris Flows: The proposed pipeline route traverses across numerous drainages with alluvial material. These drainages are subject to debris flow and flash flood occurrence during the sporadic heavy rainfall of the region.

Rock Falls: The Palo Verde Peak area contains moderate to steep slopes that contain blocky, volcanic rock outcrops and boulders on the surface. These outcrops are a potential source of falling and rolling boulders. Rock falls are most likely to occur during strong earthquakes or large storms that may loosen boulders on the surface. However, the proposed pipeline does not appear to be at risk from rock falls in that the route does not traverse sloping terrain exceeding 25% gradient nor is the route immediately at the foot of steep slopes.

Mesa Bank Stability (Milepost 11.6 to 11.8): The NBP route will traverse up the terrace edge of the Palo Verde Mesa (see Figure 10). The terrace slope is generally at a 25% gradient, but is locally at 30 to 35% gradient. This terrace slope is susceptible to water erosion if significant runoff occurs down the slope. The base of the terrace is densely vegetated. The terrace slope to the south appears to have been eroded by several small washes that formerly drained a larger drainage basin to the west. The drainage is now generally directed to a gulley cutting through the lower terrace about 4000 feet to the south of Milepost 11.7. There are several sand dunes at the base of the mesa to the south, giving the appearance of a hummocky topography.

River Bank Stability (Milepost 0 to 0.5): The Colorado River banks may be susceptible to failure during an earthquake or flooding. Horizontal directional drilling for the pipeline crossing will be well below and away from potential areas of bank instability.

3.5.5 Erosion and Scour

Evidence of erosion was observed in numerous alluvial washes (arroyos) on the Palo Verde Mesa. Erosion and scour of fluvial washes is considered a significant risk along significant portions of the NBP route (mainly from Mileposts 16.5 to 73). The NBP route crosses mesas and piedmonts that are generally depositional from outwashes from higher mountainous terrain. The existing alluvial washes may meander laterally from existing channels during flooding and possibly scour to deeper depths. We understand that soil cover of up to 5-feet depth and possible concrete encasement are being considered to mitigate this hazard across significant washes.

Section 4
CONCLUSIONS

The following is a summary of our conclusions and professional opinions based on the data obtained from a review of selected technical literature, geologic and topographic maps, and limited site reconnaissance.

<u>Geologic Constraints and Mitigation:</u>

- The primary geologic hazard along the North Baja Pipeline is moderate ground shaking from earthquakes and resulting soil liquefaction originating on distant faults. A major earthquake of magnitude 7 or greater originating on the San Andreas or Imperial Valley Faults would be the critical seismic event that may affect the proposed North Baja Pipeline. The ground motion potential becomes stronger along the IID lateral. Engineered design and earthquake-resistant construction increase safety and allow development of seismic areas.

- The project study areas lie within seismic Zones 3 and 4 and about 0 to 113 km from Type A seismic sources as defined in the California Building Code. The *minimum* seismic design of the pipeline and facilities should comply with the latest edition of the California Building Code and ASCE 7-03.

- ***The IID Lateral crosses the active Imperial fault.*** Earthquake resistant design should accommodate an estimated 5 to 15 feet of fault displacement.

- Other seismic hazards including ground rupture and seismically induced flooding are considered low or negligible for the proposed North Baja Pipeline.

- A significant probability for soil liquefaction may occur for a design basis earthquake at the Ehrenberg Compressor site, the Arizona side of the Colorado River crossing, and western portion of the 18th Avenue alignment. Some areas around the Palo Verde Peak are susceptible to soil liquefaction where the pipeline traverses across recent alluvium at the base of foothills to the mountains. A significant potential for soil liquefaction occurs along the IID lateral within the Imperial Valley. The pipeline should be designed to be earthquake resistant using the estimated Peak Ground Velocity (PGV) and Permanent Ground Displacement (PGD) values given in this report.

- The North Baja Pipeline route crosses generally gently sloping terrain with gradients less than 25%, except at the edge of the Palo Verde Mesa at Milepost 11.6 to 11.8. Except at this area the potential for slope instability is low to nil. To avoid a potential instability of the NBP at the Palo Verde Mesa, the pipeline and the grade immediately to each side of the pipeline should be laid back to no more than 30% gradient for the estimated 60-foot high lower terrace slope. Minor cuts are anticipated to accommodate this grade transition.

- Fluvial scour erosion is possible within existing alluvial washes that dissect the older alluvium mesas and piedmonts. Deeper soil cover and possible concrete encasement are possible measures to mitigate this hazard across significant washes.

Section 5
LIMITATIONS

Our findings and recommendations in this report are based on selected points of field exploration, review of maps and geologic data, limited site reconnaissance, and our understanding of the proposed project. Variations in soil, rock, or groundwater may require additional studies, consultation, and possible design revisions.

Findings of this report are valid as of the issued date of the report. However, changes in conditions of a property can occur with passage of time whether they are from natural processes or works of man on this or adjoining properties. In addition, changes in applicable standards occur whether they result from legislation or broadening of knowledge. Accordingly, findings of this report may be invalidated wholly or partially by changes outside our control. Therefore, this report is subject to review and should not be relied upon after a period of one year.

In the event that any changes in the nature, design, or location of the pipeline are planned, the conclusions contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report are modified or verified in writing.

This report is issued with the understanding that the owner, or the owner's representative, has the responsibility for submittal of this report to the appropriate governing agencies.

Earth Systems Southwest (ESSW) has striven to provide our services in accordance with generally accepted geotechnical engineering practices in this locality at this time. No warranty or guarantee is express or implied. This report was prepared for the exclusive use of the Client and the Client's authorized agents.

Although available through ESSW, the current scope of our services does not include an environmental assessment, or investigation for the presence or absence of wetlands, hazardous or toxic materials in the soil, surface water, groundwater or air on, below, or adjacent to the subject property.

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Appendices as cited are attached and complete this report.

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Aerial Photographs Reviewed

Date	Frame Numbers	Scale	Source
2-23-95	48-6, 48-7, 48-8	1" = 1,650'	Riverside County Flood Control District